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Ultrasonic Enhancement of Industrial Sludge Settling Ability and Dewatering Ability*

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Abstract: This paper investigates the treatment of chromium (Cr) contaminated industrial sludge from a tanning process with ultrasound to enhance the sludge settling ability and dewatering ability. Ultrasound at various frequencies, intensities, and time was tested to optimize the operation. The results show that treatment with 30 kHz, 12 W/L ultrasound for 120 s shortened the sludge settling time from 3 h to 1 h and reduced the supernatant Cr concentration. The ultrasonic treatment also reduced the sludge volume from 4.02 mL/g to 2.58 mL/g and increased the sludge Cr concentration by 2/3. The treated sludge could then be reused in the tanning operation. Proper ultrasonic treatment can significantly reduce the sludge volume and enhance the Cr reuse.

Key words: ultrasound; industrial sludge; sludge volume; Cr

Introduction

Today, sludge management represents a major investment due to the high operating costs and presents many important technical challenges. The associated capital and operating costs may be as high as 25%-50% of the total cost of the wastewater treatment process. The bottleneck in the sludge handling system is the dewatering operation. Various processes using thermal hydrolysis (neutral, acid, alkaline) or chemical oxidation (H_2O_2, O_3, O_2) have been proposed in the literatures[1, 2].

Recently, more attention has been paid to the ultrasonic pretreatment of sludge to reduce environmental pollution[3-13]. Ultrasound produces pressure waves that propagate through a medium with a vast amount of energy dissipation[3] which generates gas and vapor bubbles which grow and collapse violently at high velocity. The phenomenon is termed “acoustic cavitation” and occurs more readily at frequencies of 20-100 kHz[14]. Strong turbulent eddies of size 5-100 μm are induced around the collapsing bubbles. High temperatures (5000 K) and pressures (100 MPa) developed inside the collapsing bubbles can induce many physicochemical effects. The acoustic cavitation produces large shear forces that act on the substances in the liquor[8,13]. The hydro-mechanical shear forces produced by ultrasonic cavitation are predominantly responsible for sludge disintegration[6].

The characteristics and structure of sludge greatly influence the degree of hydration, which is closely related to the volume. Structural and property changes in the sludge also influence the dewatering process which is also connected with the breaking of chemical bonds between the water and solids surfaces. Changes in the bond strength simplify water-particle separation during mechanical dewatering[7]. Many studies have shown

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that ultrasonic treatment induces changes of the sludge structure which improves thickening and dewatering. Investigations proved that the dewatering ability of sewage sludge strongly depended on the size of the suspended particles[5]. Therefore, some authors have speculated that the ultrasound treatment improves the sludge thickening process by breaking the sludge flocs[9]. As a result, some of the insoluble particulate organic matter is transformed into soluble material[9-11]. While short sonication destroys the sludge floc agglomerates, it does not affect cells. Long sonication will break the cell walls as well as the sludge solids which will more effectively release the dissolved organic compounds[6], all of which affect the sludge settling ability.

Most previous studies have focused on accelerating the anaerobic digestion of activated sludge and have found that ultrasonic treatment effectively shortens the digestion time and increases the bio-gas production. However, only a few studies have analyzed the enhancement of sludge settling ability and dewatering ability, which are also very important. This paper presents a study of the effect of ultrasonic treatment on the sludge settling ability and dewatering ability of industrial sludge to reduce the sludge volume and improve the reuse characteristics. The sludge was from a tanning operation, so it contained high levels of organics and Cr^{3+} and was classified as hazardous waste. When properly treated, the concentrated sludge could be reused in the tanning process. Therefore, the goal of the sludge treatment is to minimize the sludge volume and increase the sludge Cr^{3+} concentration.

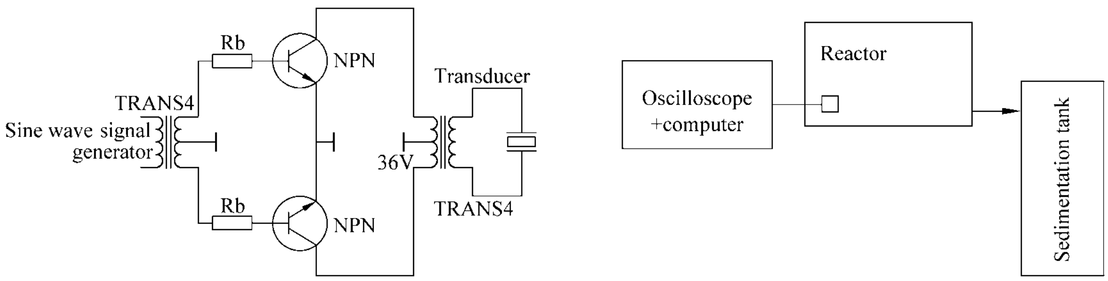
1 Materials and Methods

Sludge samples were collected from the chemical precipitation tank of a small tannery in Shenzhen, China. The collected samples had a water content of 92.5%±0.8% and a Cr^{3+} concentration of (5300±75) mg/L. The samples were continuously aerated at room temperature. All analyses were conducted following national standard methods unless stated otherwise.

Sonication was conducted in a home-made stainless steel reactor 30 cm long and 15 cm wide. The ultrasound generator consisted of a voltage controlled oscillator (VCO), a power amplifier, and a matched impedance and feedback unit (Fig. 1). The sound waves were emitted from piezo-electric discs of lead zirconate titanate glued to the reactor bottom. The sound was monitored by dipping a broadband polyvinylidene fluoride (PVDF) probe-type hydrophone (Institute of Acoustics, Chinese Academy of Sciences) into the suspension 1 cm above the reactor bottom. The hydrophone had a sensitivity of about 31.3 nV/Pa in the frequency range involved in this investigation. The output signal from the hydrophone was transmitted to an oscilloscope (TDS520, Tektronics Inc), digitized, and stored in a computer. The cavitation spectra were analyzed using the Origin software (Version 6.1, Originlab Corp.) to get the sound frequency and acoustic pressure with a reference acoustic pressure of 10^{-6} Pa. The measured ultrasonic frequencies were 29, 62, and 83 kHz and the sound power was 50-400 W. Figure 2 shows that the sound distribution inside the reactor was even. The levels of the ultrasonic parameters were selected based on previous studies.

15 L sludge was first treated in the ultrasonic reactor and then allowed to flow by gravity into a cylindrical glass column for sedimentation. The column was 2 m long with an inner diameter of 10 cm. The sludge was allowed to settle for 3 h. After sedimentation, 500 mL sludge was sampled for mechanical dewatering with a centrifuge at 3000 r/min for 5 min. The dry sludge and supernatant were then analyzed.

The sludge particle size distribution was measured



(a) Electrical circuit of ultrasonic reactor (b) Experimental system

Fig. 1 Schematic system

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